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METHOD AND RECEIVER FOR THE SIMULTANEOUS DETECTION AND ANALYSIS OF AT LEAST TWO ELECTROMAGNETIC SIGNALS

The present invention relates to a method and a receiver for the simultaneous detection and analysis of at least two electromagnetic signals. Such a method or such a receiver can particularly be used in a spacecraft. Spacecraft in the sense of the invention are all artificial bodies designed for use in outer space, particularly also satellites, space probes, space shuttles, space stations or rockets. However, in principle, the method and the receiver can also be used for terrestrial applications. Receivers in the sense of the invention are all devices which are designed for receiving and processing electromagnetic radiation, for example, for the purpose of the data exchange between spacecraft, or between the spacecraft and earth stations, or between other objects, or also for the purpose of the detection, locating, measuring and/or observation of objects emitting electromagnetic radiation. Signals in the sense of the invention are represented by any type of electromagnetic radiation which can be detected by a receiver according to the invention; thus, radiation actively emitted by an object as well as passively scattered or reflected by an object.

From the state of the art, an optical receiver system is known from German Patent Document DE 198 46 690 A1, which is constructed in the form of a combined earth-star sensor. The latter is used for observing the earth and the stars. From the obtained information, a three-axis attitude and position determination of satellites is permitted.

An optical receiver system for optical intersatellite connections is known from German Patent Document DE 198 47 480 A1. The corresponding optical receiver is described in sufficient detail in German Patent Document DE 198 47 480 A1. Such intersatellite connections are used for exchanging data between individual satellites but can also be utilized for determining the attitude of a satellite, as in the case of German Patent Document DE 198 47 480 A1.

However, a problem arises in the case of arrangements from the state of the art when simultaneously two or more electromagnetic signals are to be detected which are mutually superimposed on a common detector. Here, it has to be possible to nevertheless carry out a sufficient separation of the individual electromagnetic signals which permits a clear identification of the individual electromagnetic signals. It is another problem that a distortion of detected radiation images often occurs in the area outside the optical axis of the receiver. This is particularly relevant when one of the electromagnetic signals has

to be determined with a particularly high precision. The arrangements from the state of the art offer no satisfactory solution for this purpose.

It is therefore an object of the invention to provide a method and a receiver for the simultaneous detection and analysis of at least two electromagnetic signals which eliminates the disadvantages of the state of the art.

This object is achieved by means of the characteristics of Claims 1 and 8.

A first object of the present invention relates to a method for the simultaneous detection and analysis of at least two electromagnetic signals by a joint detector, the detection and analysis of at least one radiation image signal taking place.

According to the invention, the method comprises the following steps:

- Division of an input radiation image into at least two partial images
- Projection of the partial images on a radiation detector,
- an imagining of the partial images on the radiation detector taking place such that radiation intensities of the partial images are projected from the image center of the input radiation image to the edge of the radiation image on the

detector.

In this case, a planar expanded electromagnetic radiation signal is considered to be the radiation image signal, which radiation signal appears as an image and not only as in a largely punctiform shape when it is projected on the detector.

The advantage of the method according to the invention consists of the fact that the radiation image, which as an expanded radiation signal is less susceptible to distortions, is displaced into edge areas, whereby the area around the optical axis can be utilized for the - simultaneous - detection of less expanded signals, which can now, however, take place in a more precise manner. This applies particularly if, in addition to the radiation image, the exact position of another signal of a smaller expansion is to be detected. In addition, a mutual interfering influence of the signals to be simultaneously detected can be avoided or at least reduced as a result of the displacement of the radiation intensities of the partial images into the edge area. This is particularly applicable when the radiation intensities of the radiation image are approximately equally high as or even higher than the radiation intensity of the at least one other signal. The detector surface can also be used more effectively by the displacement of the radiation intensities from the image center of the radiation image into the edge area.

The projection of the radiation intensities of the partial images from the image center of the input radiation image to the edge of the radiation image can particularly take place in that the partial images of the input radiation image are reflected. However, as an alternative, it can also be provided that the partial images of the input radiation image are displaced in the direction of the image edge.

The division of the input radiation image can take place into any suitable number and shape of partial images which permit the displacement of the radiation intensities from the image center of the input radiation image to the edge of the radiation image. Thus, in the case of a square input radiation image, in can particularly be provided that a division of the input radiation image takes place into four partial images and an imaging of the partial images takes place such that radiation intensities are projected from the image center of the input radiation image in the direction of a corner of the radiation image on the detector. However, basically, for example, a division into only two partial images or into a larger number of partial images may also take place.

In principle, the method according to the invention can be used for all suitable types of electromagnetic signals, one of these signals being present as a radiation image signal. Thus,

for example, a data communication signal can be detected as one of the electromagnetic signals, for example, in addition to a radiation image signal. A usage for this purpose can take place, for example, within the scope of data connections between objects, such as particularly spacecraft or the like. For this purpose, reference is also made to the statements in the introduction to the specification.

In a special application of the present method, it may be provided that radiation images of reference objects, particularly celestial bodies, are detected as radiation image signals. This can be provided particularly when an identification or position determination of certain reference objects, such as particularly celestial bodies, is to take place. By means of the obtained information, for example, a position information and/or attitude information can then be obtained relative to the corresponding reference object. However, in addition to this detection of one or more reference objects, other electromagnetic signals, such as those of largely punctiform signal sources can also be detected, which may be used, for example, for obtaining additional position information and/or attitude information but also, for example, for the data communication.

A special embodiment of the above-mentioned method, which is used particularly for spacecraft, provides that simultaneously radiation images of the earth and the stars are detected and the

image of the earth is divided into partial images. As a result, it can be achieved that the, as a rule, largely punctiform electromagnetic signals, which usually have a lower intensity, can be detected in the optical axis of the detector - thus largely without any distortion -, which permits a precise position determination of the stars. In contrast, the more expanded and, as a rule, higher-intensity radiation image of the earth is displaced to the edge of the detector, thus into an area outside the optical axis of the detector. Thus, a detection of the earth and the stars is permitted with a greater precision than in the state of the art while the mutually influencing of the respective signals is simultaneously reduced.

Another object of the present invention is a receiver having a device for the simultaneous detection and analysis of at least two electromagnetic signals by a joint detector, the device being designed for the detection and analysis of at least one radiation image signal. According to the invention, at least one radiation image splitter is now provided for dividing the input radiation image into at least two partial images as well as for projecting the partial images onto a radiation detector, which is designed such that an imaging of the partial images onto the radiation detector takes place in such a manner that radiation intensities of the partial images are projected from the image center of the input radiation image to the edge of the radiation image on the detector. Analogously, the advantages which were illustrated for

the method according to the invention are obtained for the receiver according to the invention.

In particular, the radiation image splitter can be designed such that the partial images of the input radiation image are reflected. However, the radiation image splitter may also be designed in such a manner that the partial images of the input radiation image are displaced in the direction of the image edge.

For the case of a square input radiation image, the radiation image splitter can particularly be designed such that the division of the input radiation image takes place into four partial images and an imaging of the partial images takes place such that the radiation intensities are projected from the image center of the input radiation image in the direction of a corner of the radiation image on the detector.

In particular, the receiver can be constructed as part of a data communication device. For this purpose, reference is made to the statements concerning the method according to the invention.

The receiver can also be designed as a sensor for the detection of radiation images of reference objects, particularly of celestial bodies. In this respect, reference is also made to

the statements concerning the method according to the invention. A combination with another detection method of signals, for example, for the data communication, can also be provided in the case of the receiver according to the invention. The receiver may be designed, for example, as a combined earth-star sensor.

In principle, the receiver can be designed for any suitable wavelength or any suitable wavelength range. In particular, it can be provided that the receiver is designed as an optical receiver.

A special embodiment of the present invention will be illustrated in the following by means of Figures 1 to 7 on the example of an optical receiver.

Figure 1 is a schematic representation of an optical receiver according to the invention;

Figure 2 is a schematic representation of the division of an input radiation image into partial images;

Figure 3 is a schematic representation of the projection of displaced partial images on the detector;

Figure 4 is a schematic representation of the projection of reflected partial images on the detector;

Figure 5 is a representation analogous to Figures 1 and 2 without a radiation image splitter for a combined earth-star sensor;

Figure 6 is a representation analogous to Figures 1 and 4 with a prism arrangement as a radiation image splitter for a combined earth-star sensor;

Figure 7 is a representation analogous to Figures 1 and 4 with a mirror arrangement as the radiation image splitter for a combined earth-star sensor.

Figure 1 is a purely schematic view of a special embodiment of an optical receiver 1 according to the present invention. This receiver 1 has a first expanded aperture 2 for the detection of an expanded optical radiation image signal and a second aperture 3 for the detection of less expanded optical signals. In the example according to Figure 1, the two apertures 2, 3 are arranged perpendicular to one another. However, another suitable arrangement of the apertures 2, 3 is also conceivable.

The radiation image signal entering through the aperture 2 is projected on an optical detector 6. The optical signal entering through the aperture 3 is projected on the detector 6, for example, by way of a mirror 5. For the implementation or

optimization of the projection, a correspondingly constructed imaging lens system 10 can additionally be provided. The optical radiation image signal and the additional optical signal are then mutually superimposed on the detector 6. The mirror 5 can also be constructed as a semitransparent mirror. As a result, a superposition of the two optical signals can already take place by means of the semitransparent mirror.

Figure 2 shows the situation of the superposition of the two optical signals, as it would occur without any further influence on the radiation image signal. It is assumed that a square optical input radiation image 9 is the radiation image signal, the input radiation image 9 containing the optical image of a reference object 7. Furthermore, another largely punctiform signal 8 is assumed which was detected by the aperture 3. The additional, largely punctiform optical signal 8 would then normally be superimposed on the input radiation image signal 9. As illustrated in Figure 2, signal 8 is imaged in the image center and thus in the optical axis of the detector 6 in order to avoid distortions, if possible. However, in this case, especially the optical image of the reference object 7 is superimposed on the optical signal 8, which makes a separation of the optical signal 8 from that of the reference object 7 difficult.

In order to avoid this problem, the input radiation image 9

is divided into two partial images TB1 and TB2, before a superposition takes place with the additional optical signal. The two partial images are already illustrated in Figure 2. For this purpose, a radiation image splitter 4 is provided in the optical receiver, as purely schematically shown in Figure 1. However, a division can also take place into more than only two partial images or into partial images having a different shape.

The radiation image splitter can now be designed such that either the partial images TB1 and TB2 are displaced toward the image edge in such a manner that the radiation intensities are displaced from the image center of the input radiation image 9, thus the image parts of the reference object image 7, to the image edge. This is illustrated in Figure 3. Only the optical signal 8 will now remain in the image center and can now be detected without being influenced by the radiation image of the reference object 7. Also, the surface of the detector 6 is now utilized more effectively because also the edge areas are utilized for a signal detection.

Figure 4 illustrates an alternative to Figure 3, in which no displacement but a suitable reflection of the partial images TB1, TB2 takes place. As a result of this suitable reflection, the radiation intensities are again imaged from the image center of the input radiation image 9, this the image parts of the reference object image 7, onto the area of the image edge. As a

result, as in the case of Figure 3, the optical signal 8 can now be detected without being influenced by the radiation image of the reference object 7.

The additional optical signal 8 may, for example, represent an optical data communication signal but also a largely punctiform reference signal of an artificial or natural radiation source, such as a star. Thus, either information within the scope of a data transmission can be obtained from the optical signal 8, or corresponding position or attitude information can be obtained concerning a position determination of the origin of the optical signal 8.

Figure 5 now illustrates a special embodiment of the optical receiver 1 of the above-mentioned example within the scope of a combined earth-star sensor. The latter also has two apertures 2, 3 as well as an arrangement 5, such as a semitransparent mirror, for the superposition of two radiation image signals 8, 9 - here, the input radiation image 9 of the earth 7 and the radiation image signal 8 of selected stars 12 -. The two superimposed radiation image signals 8, 9 are then imaged on a detector 6 by a suitable lens system 10. In the case according to Figure 5, the two radiation image signals 8, 9 would therefore be imposed on one another such that the optical signal 8 of the stars 12 would be superimposed on the optical input radiation image 9 of the reference object earth 7 directly in the optical axis 11 of the

detector 6, as shown in Figure 5 on the right. As a result, the signal 8 of the stars 12 could hardly be separated from the radiation image signal 9 of the earth 7 because of the higher radiation intensity of the radiation image signal of the earth 7.

In order to avoid this, four partial images TB1 to TB4 of the radiation image signal 9 of the earth 7 are generated which, by means of an optical imaging, for example, by means of prism arrangements or mirror arrangements, are displaced to the image edge of the input radiation image 9. This is illustrated in Figures 6 and 7.

Figure 6 shows an example in which a prism arrangement is used. However, during the selection of the suitable prism arrangement, attention should be paid to the fact that an achromatic imaging of the radiation images takes place if the radiation images are not monochromatic radiation image signals. This problem can basically be avoided if, instead of a prism arrangement, a reflective arrangement by means of appropriately arranged and appropriately shaped mirrors is used, as illustrated in the manner of an example in Figure 7.

In the example according to Figure 6, a radiation image splitter 4 with a suitable prism arrangement is connected in front of the semitransparent mirror, which prism arrangement causes a quadruplication of the input radiation image 9 while

simultaneously displacing the individual radiation images with respect to one another in the direction of the corners of the original input radiation image 9. In this case, only the displaced partial images TB1 to TB4 are detected in the corners on the detector 6 illustrated on the right in Figure 6. In contrast, only the optical signal 8 of the stars 12 is imaged in the optical axis 11 of the detector. On the detector 6, the stars 12 have a much smaller expansion and therefore appear largely in a punctiform shape. By means of the arrangement according to Figure 6, it is ensured that the position of the stars 12 can be detected largely without distortions and without interfering impairments by the radiation image of the earth 7 and, as a result, more precise position and attitude information for the earth-star sensor can be obtained with respect to the earth 7 and the stars 12.

The arrangement according to Figure 7 corresponds largely to the arrangement according to Figure 6. For a simplification and better clarity of the representation, the apertures 2, 3 are not shown in Figure 7. These apertures would also have to be provided here corresponding to Figure 6. In the example according to Figure 7, the prism arrangement 4 was replaced by a mirror arrangement 13 which consists of a central metal-coated body 14 and several planar mirrors 15 which partially surround the body 14 but leave open at least a beam path for the entering and exiting of the radiation image from the mirror arrangement

13. By using such a mirror arrangement 13, a detection of arbitrary radiation images can take place independently of their spectral composition.